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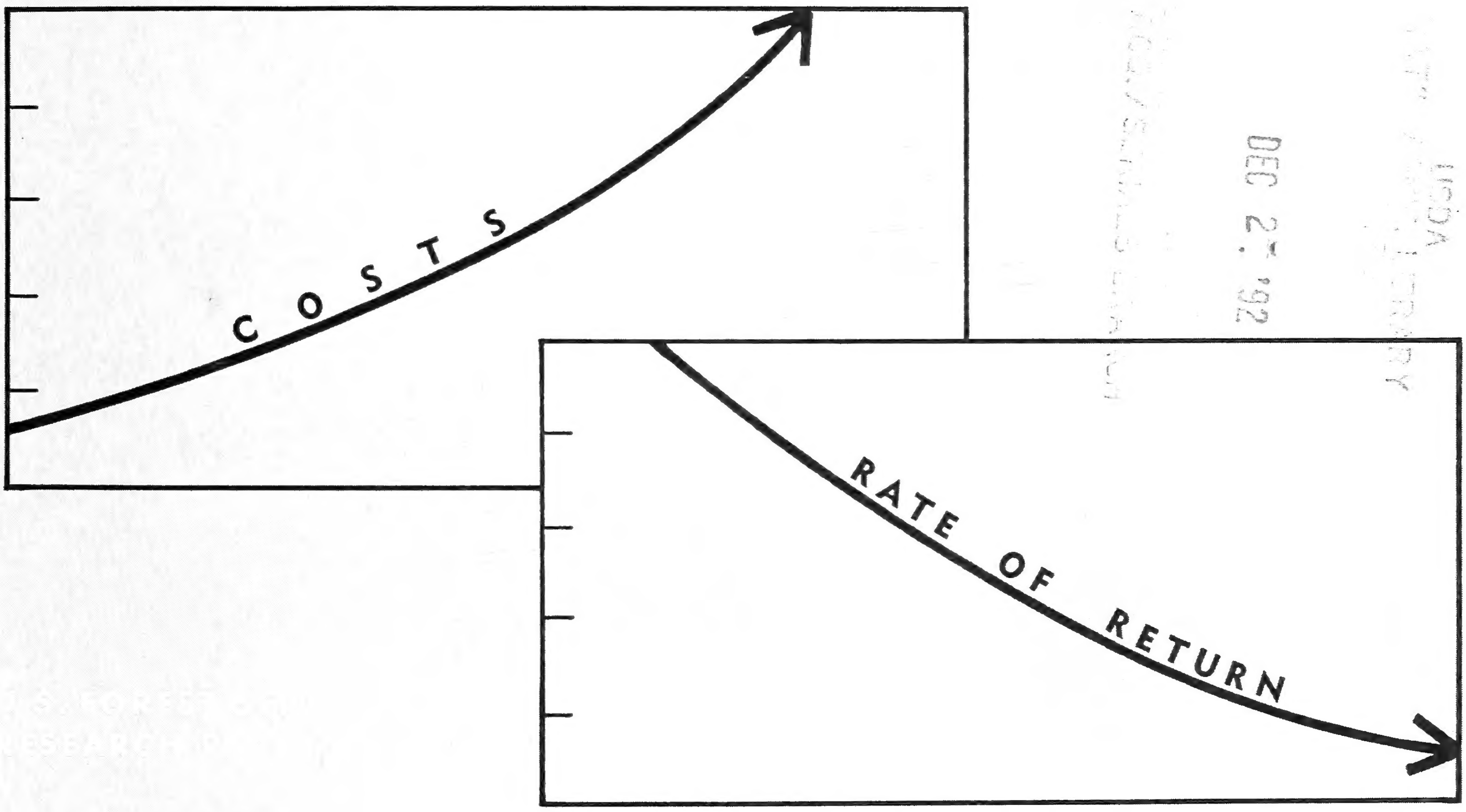
COSTS
RATE OF RETURN

PREFACE

The size of this publication is scarcely indicative of the research effort on which it is based. Many individuals throughout the West participated in the 5-year undertaking. At the Rocky Mountain Forest and Range Experiment Station, Stuart Andrews and Frank Hawksworth provided a substantial quantity of data from their continuing studies of dwarfmistletoe behavior and impact in the Southwest. T.W. Childs and James Edgren at the Pacific Northwest Forest and Range Experiment Station, assisted by Ray Yoder of Oregon State University, undertook research directed toward both provisional and definitive quantification of dwarfmistletoe impact on ponderosa pine in the Northwest. Floyd Johnson and Dorothy Martin advised on statistical, mathematical, and computational matters. George Meagher and Carl Berntsen were consulted about ponderosa pine silviculture.

Benton Howard, of U. S. Forest Service Region 6 Regional Office, and Barney Duberow, Deschutes National Forest, coordinated the extensive control cost studies. Donald Graham, Regional Office, and Kenneth Dykeman, James Simonson, and Robert Pederson, Deschutes National Forest, participated in planning and field supervision of the work.

The overall economic study was initiated by Carl Newport, Pacific Northwest Station; John Fedkiw, now with the U.S. Forest Service, Washington Office; and Robert McMahon, now at Yale University.

Although every effort has been made to incorporate the most recent information on ponderosa pine and dwarfmistletoe behavior, important advances in information and control philosophy are continuously underway. The high cost of present control methods considered, it is hoped that the guidelines presented here will in time be made obsolete by such advances.

CONTENTS

INTRODUCTION

Figure 1.--Ponderosa pine dwarfmistletoe.

This publication suggests economic guides--costs and rates of return--for selecting control areas and controlling ponderosa pine dwarfmistletoe (fig. 1). It is intended for the practicing forester in the Northwest who wants criteria for distributing a limited management budget among several management opportunities on many different stand types and site conditions.

The effects of mistletoes on their hosts have been observed for many years.[1] Dwarfmistletoe reduces vigor and causes large brooms and enlarged branches which, in turn, reduce wood production and seed quantity and viability and may eventually induce early mortality.

The species of ponderosa pine dwarfmistletoe involved in this report are *Arceuthobium vaginatum* and *A. campylopodum* (Engelm.) f. *campylopodum* (Gill 1954).

Dwarfmistletoe is apparently ubiquitous; it has been found in all parts of the range of ponderosa pine (Gill and Hawksworth 1961, *p.45*) except the Black Hills, although its intensity is highly variable. Studies of dwarfmistletoe intensity and its impact on ponderosa pine have encompassed only portions of the West. The most extensive survey was that of Andrews and Daniels (1960) on the National Forests and Indian Reservations of Arizona and New Mexico. Thirty-six percent of their ponderosa pine plots had some degree of infection, suggesting that 2.5 million acres of commercial ponderosa pine timberland are infected there. Hawksworth and Lusher

[1] A comprehensive survey of literature on the entire mistletoe family (Loranthaceae) has been prepared by Gill and Hawksworth (1961). A cross section of American publications concerned with ponderosa pine might include Andrews (1957), Childs (1963), Gill (1954), Gill and Hawksworth (1954), Hawksworth (1961), Hawksworth and Lusher (1956), Herman (1961), Kimmey (1957), Korstian and Long (1922), Linnard (1961), Roth (1954), Wagener (1961), and Weir (1916). Names and dates in parentheses refer to Literature Cited, p. 15.

(1956) found that 53 percent, or 88,000 acres, of the ponderosa pine type on the Mescalero Reservation were infected. In the Northwest, Roth (1953) found patch-like infection of 32 acres on a 160-acre tract of typical virgin forest in eastern Oregon. Childs and Greene,[2] in a survey of part of the Deschutes National Forest in Oregon, found ponderosa pine dwarfmistletoe infection in small, scattered patches on 18 percent of their 3,128 stocked plots.

In southern California, "The disease is widely distributed and has built up locally to epidemic proportions"; and a statewide survey revealed that dwarfmistletoe was present on 30 percent of plots in the ponderosa pine type (U.S. Forest Service 1960, *pp. 42-47*).

Without question, the spread of dwarfmistletoe, a seed-bearing parasite, can be controlled. Apparently, lateral spread of the plant through even-aged stands is not more than about 2 feet per year (Hawksworth 1961, Roth[3]). Where overstory trees allow dwarfmistletoe seed to fall on an understory, the maximum range of overhead dispersal is about 130 feet (Roth 1953). It appears that birds and rodents are not important local transporters of dwarfmistletoe seed (Hawksworth 1961, *p.66*). Thus, control can be achieved by removing or pruning infected trees.

Knowledge about the productivity of infected stands under different stocking, tree size, and infection conditions is limited. Indeed, little is known about the growth of partially stocked ponderosa pine stands such as would result from removal of infected trees. Further, many factors affect the economic feasibility of dwarfmistletoe control. To deal with the complex relationships, a number of assumptions and mathematical equations have been employed. Some are indicated in the text; others are explained in a forthcoming report which also explains the data used.[4]

METHODS OF CONTROL

Control of dwarfmistletoe requires removing infected branches or, where the parasite has become established on the trunk of a tree, felling the entire tree. Because the endophytic system of the dwarfmistletoe plant within the branch of a host tree may extend ahead of visible shoots, it is necessary to assume that dwarfmistletoe branch infections, visible close to the trunk of a tree, have already invaded the stem.[5]

[2] Childs, T.W., and Greene, W.B. Dwarfmistletoe surveys on the Deschutes National Forest, 1958. 34 pp. 1959. (Unpublished report on file at Pacific NW. Forest & Range Expt. Sta., U.S. Forest Serv., Portland, Oreg.)

[3] Roth, L.F. Observations of pine dwarfmistletoe, Pringle Falls Experimental Forest, July 7 to August 8, 1952. 1952. (Unpublished report on file at Pacific NW. Forest & Range Expt. Sta., U.S. Forest Serv., Portland, Oreg.)

[4] Flora, Donald F. Forecasting returns from ponderosa pine dwarfmistletoe control. (In preparation for publication, Pacific NW. Forest & Range Expt. Sta., U.S. Forest Serv., Portland, Oreg.)

[5] Hawksworth and Andrews (1961) suggest the following rule for pruning infected branches: "Branches 1.0 inch or less in diameter may be safely pruned if shoots or basal cups do not occur closer than 6 inches from the bole. For each 1-inch increase in branch diameter, the minimum safe distance is increased by 2 inches."

In the Pacific Northwest, the U.S. Forest Service has used what is termed here a pruning-felling method of control. This calls for:

1. Removal of infected overstory trees as a part of the timber harvest;
2. Thinning to remove understory trees with
   a. stem infections,
   b. limb infections close to the bole, or
   c. so many branch infections as to make pruning impractical;
3. Pruning infected branches from the remaining trees.

Leave trees are selected by crewmen as they thin; trees are not premarked.

A "felling-only" method is used in a 10-year-old control program underway on the Mescalero-Apache Reservation of New Mexico. Sanitation involves removal of nearly all infected trees in the thinning operation (Hawksworth and Lusher 1956).[6] This results in lower stocking after sanitation, but lower total cost than where pruning is employed.

Because infections may remain latent for several years before producing visible shoots, a recleaning must be planned about 5 years after the initial operation (Hawksworth 1961, *p.36*). Subsequent periodic inspection is desirable.

SANITATION AND SILVICULTURAL THINNING AS JOINT VENTURES

The opinion that dwarfmistletoe control should accompany any silvicultural thinning operation is widely held. This reflects the conviction that thinning is itself a justifiable undertaking in too dense, uninfected stands. In infected stands, dwarfmistletoe control not only removes a source of hazard to uninfected trees but also achieves a possibly desirable reduction in stocking, making the concurrent or subsequent silvicultural thinning costs for the stand as a whole less than those for a comparable uninfected stand. Conversely, silvicultural thinning removes some infected trees.

[6] In actual practice, some 3 to 4 percent of the infected trees were pruned in the Mescalero program.

ESTIMATING THE COST OF DWARFMISTLETOE CONTROL

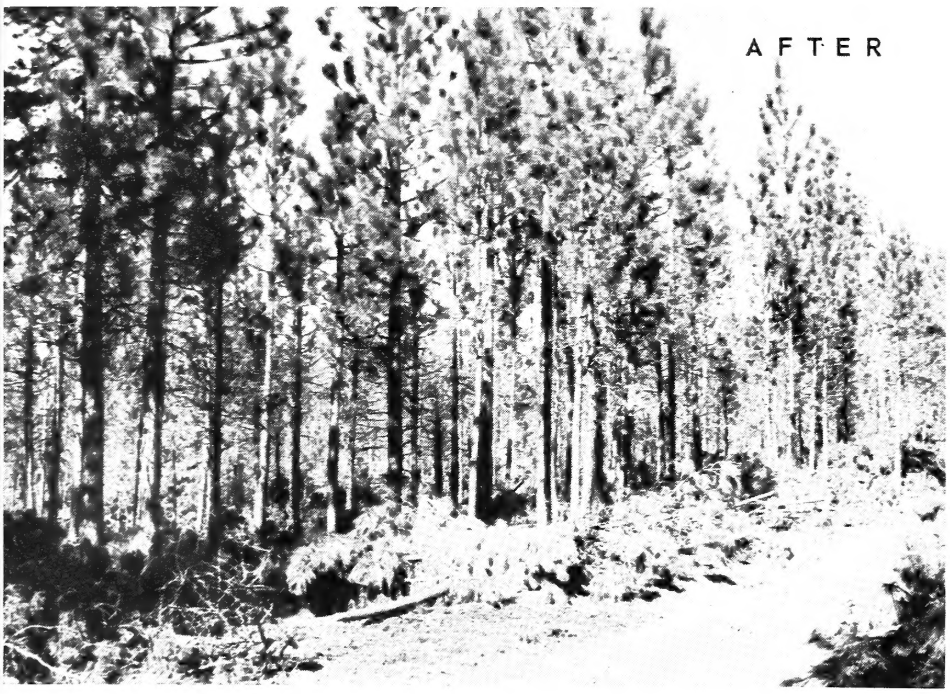

Figure 2.--One of more than 80 young ponderosa pine stands treated in the course of the economic study. Before precommercial thinning and dwarfmistletoe control, this area had 7,000 stems per acre. So dense a stand ordinarily would not be attractive treatment investment opportunity.

Figure 3.--A sectional aluminum pole saw developed by the Deschutes National Forest for pruning infected limbs from lightly infested poletimber-size trees. Such treatment may be desired where (1) the tree has almost reached merchantable size, (2) no other tree of comparable size can effectively use the growing space vacated if this tree were felled instead of pruned, (3) a young understory stand requiring protection from dwarfmistletoe is present, and (4) there is reasonable assurance that all dwarfmistletoe plants can be seen from the ground. Long-pole pruning costs, as compared with costs of alternative felling of overstory trees, are not considered in the report.

In order to identify the cost of dwarfmistletoe control with and without silvicultural treatment, time studies were conducted during 1961 and 1962 on the Deschutes National Forest in eastern Oregon. After overstory removal in timber sales, thinning of trees less than 5 inches d.b.h. was done with powered circular saws commonly called brush-cutters (fig. 2). Next, powered bow saws were employed in removing surplus stems over 5 inches d.b.h. Finally, pruning was done with 7- and 14-foot pruning saws. In a few instances, 40-foot sectional pruning saws were used to remove limited branch infections from otherwise desirable tall trees (fig. 3). The study is described in detail elsewhere.[7]

Data were collected in such a manner as to permit comparing the costs of three kinds of dwarfmistletoe treatment: (1) pruning-felling control, with additional thinning to meet silviculturally desirable stocking levels; (2) pruning-felling control, without silvicultural thinning; and (3) felling-only control, with silvicultural thinning.

COST OF PRUNING-FELLING CONTROL WITH PRECOMMERCIAL THINNING

Because costs of labor and equipment change with time, the numbers of man-hours required per acre for thinning and dwarfmistletoe pruning of infected stands are given in figures 4 and 5. Also shown

[7] Dykeman, K., and Simonson, J. Project work plan for study of dwarfmistletoe control costs. 12 pp. 1961. (Unpublished report on file at Deschutes National Forest, U.S. Forest Serv., Bend, Oreg.)

Flora, D.F. Plan for cost analysis, dwarfmistletoe control study. 15 pp. 1961. (Unpublished report on file at Pacific NW. Forest & Range Expt. Sta., U.S. Forest Serv., Portland, Oreg.)

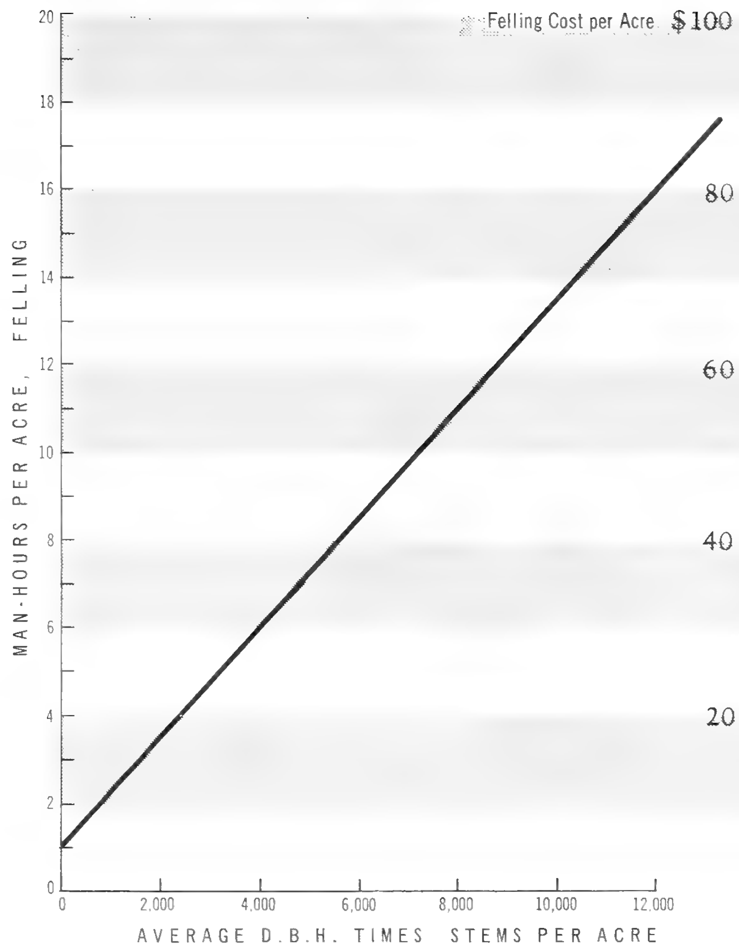

Figure 4.--Pruning-felling control with precommercial thinning; felling operation, time and cost per acre.

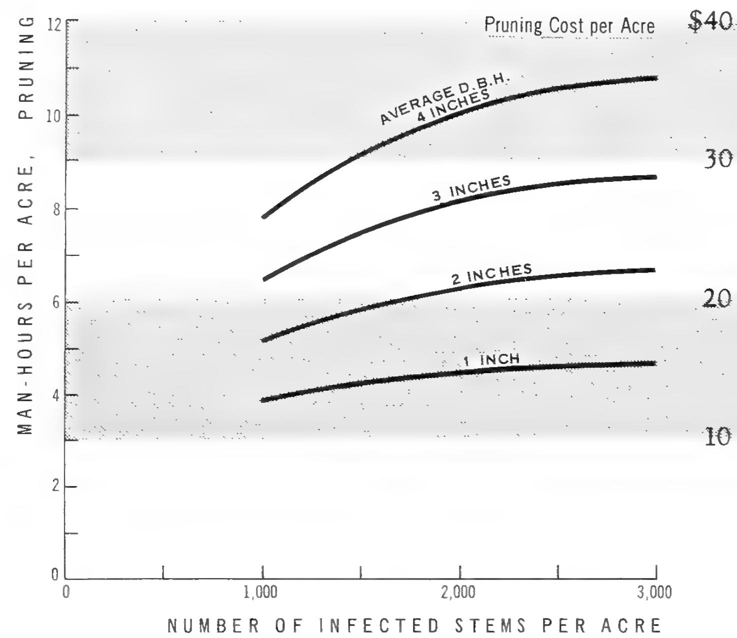

Figure 5.--Pruning-felling control with precommercial thinning; pruning operation, time and cost per acre.

are 1961-62 thinning and pruning costs per acre on the study areas. Costs are exclusive of initial reconnaissance, travel on "company time," vehicle expense, operation of camps, slash reduction, and followup removal of incipient infections.

COST OF PRUNING-FELLING CONTROL WITHOUT PRECOMMERCIAL THINNING

The Deschutes National Forest time-study data were used to estimate the cost of dwarfmistletoe felling and pruning without silvicultural thinning. Pruning time and cost per acre are the same as in figure 5. Man-hours required and cost per acre for the felling portion of control are given in figure 6.

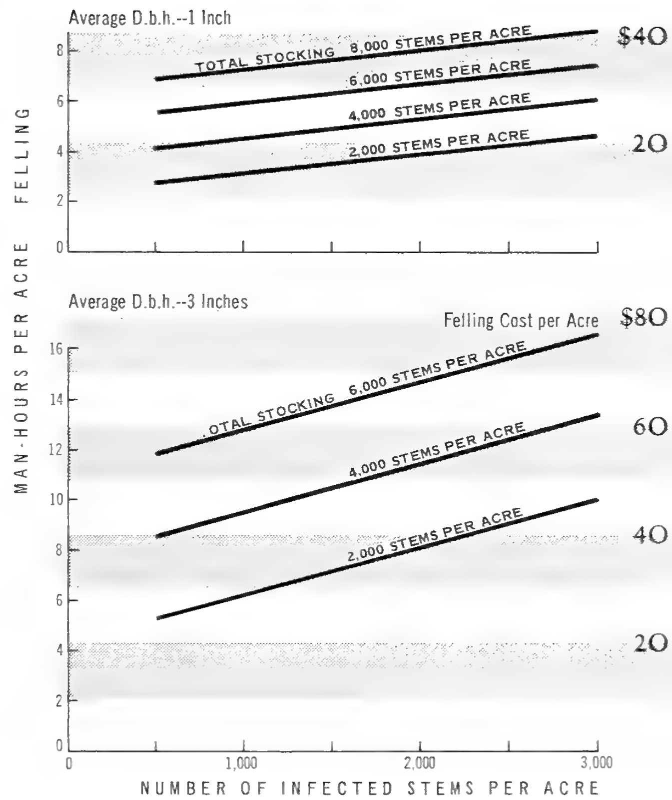

Figure 6.--Pruning-felling control without precommercial thinning; felling operation, time and cost per acre.

COST OF FELLING-ONLY CONTROL WITH PRECOMMERCIAL THINNING

No time studies have been made in the Northwest of this approach to dwarfmistletoe eradication. However, pruning-felling data for thinning in infected stands seem applicable when adjusted upward for the larger number of stems removed in the felling-only method in instances where additional trees must be felled. Figure 7 presents estimated per-acre costs for the felling-only technique, when powered brush-cutters and bow saws are used.

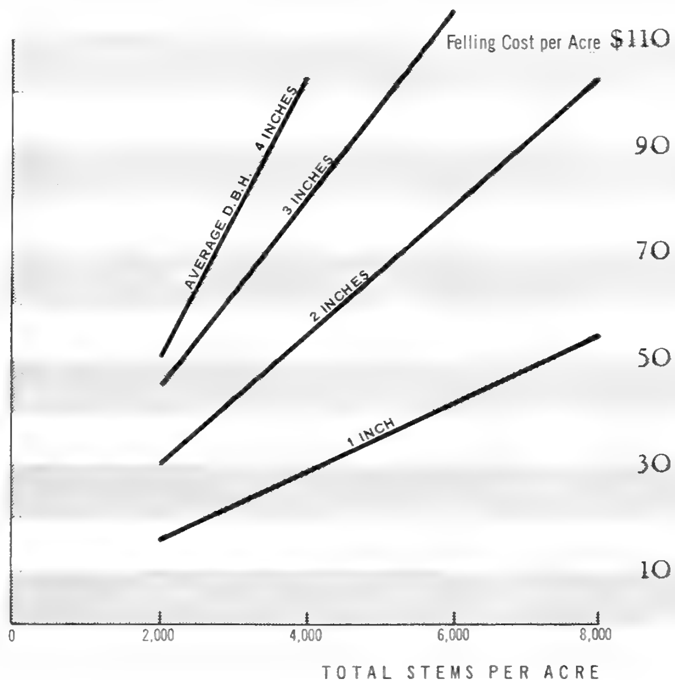

Figure 7.--Felling-only control with precommercial thinning; cost per acre.

ADDITIONAL TREATMENT COSTS

Costs discussed so far are those attributable directly to the acreage treated. There are, however, other costs that cannot be estimated from the character of the timber stand.

Travel Cost

Travel time can be an important cost element. For example, if 30 minutes of each 480-minute workday are spent in transit, a job which formerly took one 480-minute day now requires 510 minutes, so that labor cost increases by 6-1/4 percent.

The cost of vehicles can also be substantial. On the control projects associated with this study, one vehicle was required for every five men. Using a vehicle cost of 15 cents per mile, table 1 presents factors for adjusting the costs of figures 4 to 7 upward for travel. The factors allow for both labor and vehicle costs.

Reconnaissance Cost

The cost of reconnaissance to locate infected areas is not separated in this analysis. It is assumed that, in a large-scale control program, the identification and marking of infected areas is a responsibility of supervisory and overhead personnel. The cost of these persons is included in the cost estimates already presented for each method of control.

Recleaning Cost

A followup operation, about 5 years after the initial sanitation project, is an essential part of a comprehensive dwarfmistletoe control program. The cost of a recleaning, using the thinning-pruning technique outlined earlier, can only be inferred. Estimates of about $5 per acre are commonly used.

Table 1.--Factors for adjusting dwarfmistletoe control costs to include travel cost [1]

Travel time during an 8-hour shift (minutes)	Distance, round trip, miles							
	10	20	30	40	50	60	70	80
15	1.052	1.071	--	--	--	--	--	--
30	1.088	1.109	1.129	1.150	--	--	--	--
45	1.125	1.148	1.170	1.192	1.214	1.236	--	--
60	--	1.191	1.215	1.239	1.262	1.286	1.310	1.334
75	--	--	1.262	1.288	1.314	1.339	1.365	1.391
90	--	--	--	1.342	1.370	1.397	1.425	1.453

[1] Multiply estimated cost without travel by the appropriate adjustment factor. A vehicle and labor cost of 15 cents per mile is assumed.

USING THE COST CHARTS

Pruning-felling treatment cost, with or without precommercial thinning, can be estimated from figures 4 to 6 by using information on just three factors: stems per acre that are infected, total number of stems per acre, and average d.b.h. of all stems. Estimates of these factors can be made by taking plots within each stand. A grid of 1/250-acre plots has been used for this purpose where the average d.b.h. of all stems is less than 5 inches. An intensive survey would not be made, however, until a more general reconnaissance had located infected stands.

To gage the cost of treating a particular stand by the felling-only method, the total number of stems per acre and average d.b.h. of the stand must be obtained. Cost can then be estimated from figure 7.

DISCUSSION

For some areas, such as recreation sites and roadside strips, dwarfmistletoe control decisions depend strongly on factors other than economic returns. This section has explained guides for estimating the cost of dwarfmistletoe control in any stand of sapling-size timber, without considering returns. To use the guides, information must be obtained on stand density and average degree of infection.

Two methods of control, pruning-felling and felling-only, have been discussed. The cost of pruning-felling has been considered, both in combination with and separate from precommercial thinning.

Although the felling-only method is generally less costly, it does not follow that it is more economical. This method removes more trees, thereby lowering returns. The important economic measure, return per dollar of investment, is explored in the next section of this paper.

PREDICTING RATES OF RETURN FROM DWARFMISTLETOE CONTROL

There are two kinds of economic returns from eradication of dwarfmistletoe. One is increased growth and decreased mortality on the treatment area. A second comes from stands close to the treated area that would become infected if the nearby dwarfmistletoe were not removed. These returns are the difference between production if the stands are infected and production if the stands are clean.

Dwarfmistletoe control returns can be determined as follows: On the infected area, the yield from a thinned, infected stand can be subtracted from the yield of a thinned stand with dwarfmistletoe treatment. For nearby uninfected areas, the method is the same except that computations are more difficult because, as time passes, infection moves laterally through the stand and infection intensity increases within the infected part of the stand. Since tree growth and mortality depend on the size of a tree, its competition, and degree of infection, yield differs greatly depending upon distance from the initial infection source.

RATES OF RETURN ON TREATMENT INVESTMENTS

Almost every forester must divide limited funds among many worthwhile activities. His aim is to get maximum forestry benefit for each dollar spent. To meet this objective, he must rank management opportunities according to their profitability; that is, according to the expected rate of return on investment cost. High-ranked projects are undertaken in preference to low-ranked projects. Ranking by rate of return permits not only a choice between different stands being considered for dwarfmistletoe control but also comparison with other opportunities like pruning and site preparation.

Rates of return on dwarfmistletoe control, with or without precommercial thinning, are given in figures 8 to 10, using the cost-of-treatment data presented earlier (for the pruning-felling method because of its widespread use) and biological and economic information summarized below.

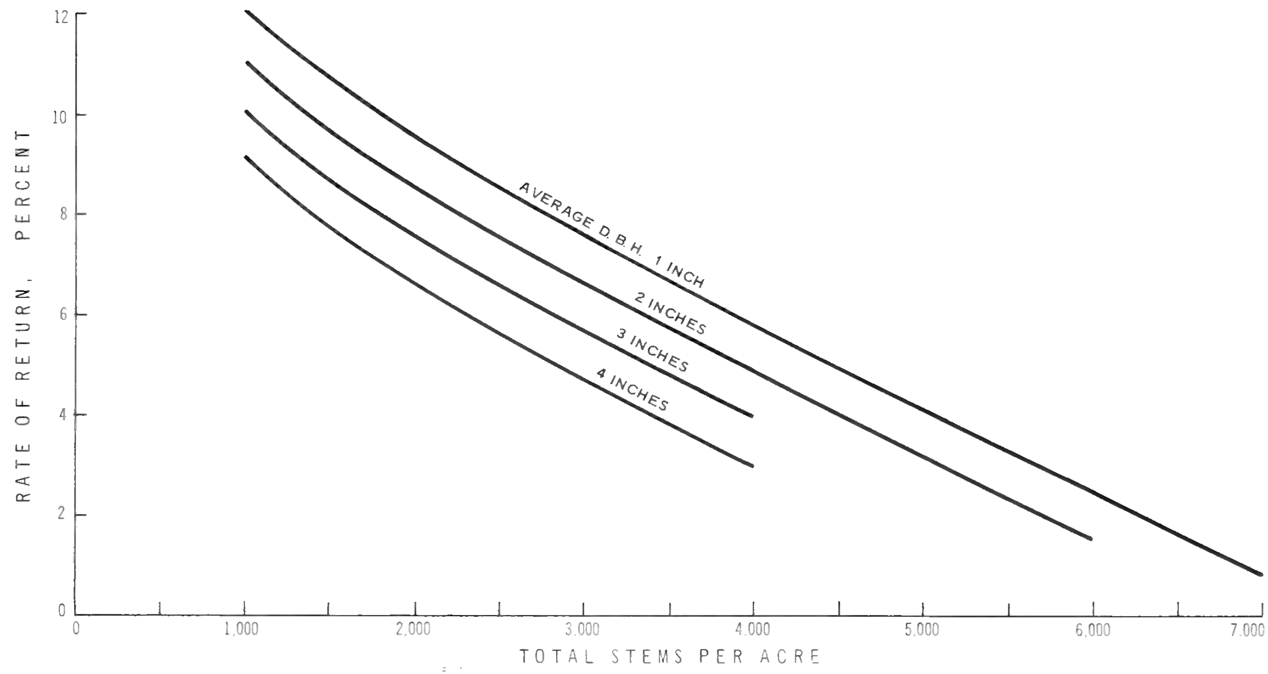

Figure 8.--Rate of return on investment. Dwarfmistletoe control with precommercial thinning. Site IV; size of infected stand, 1 acre. Rule: For each increase of site quality by one class, subtract 1/2 percent; for each increase of size of infected stand by 1 acre, subtract 1/5 percent.

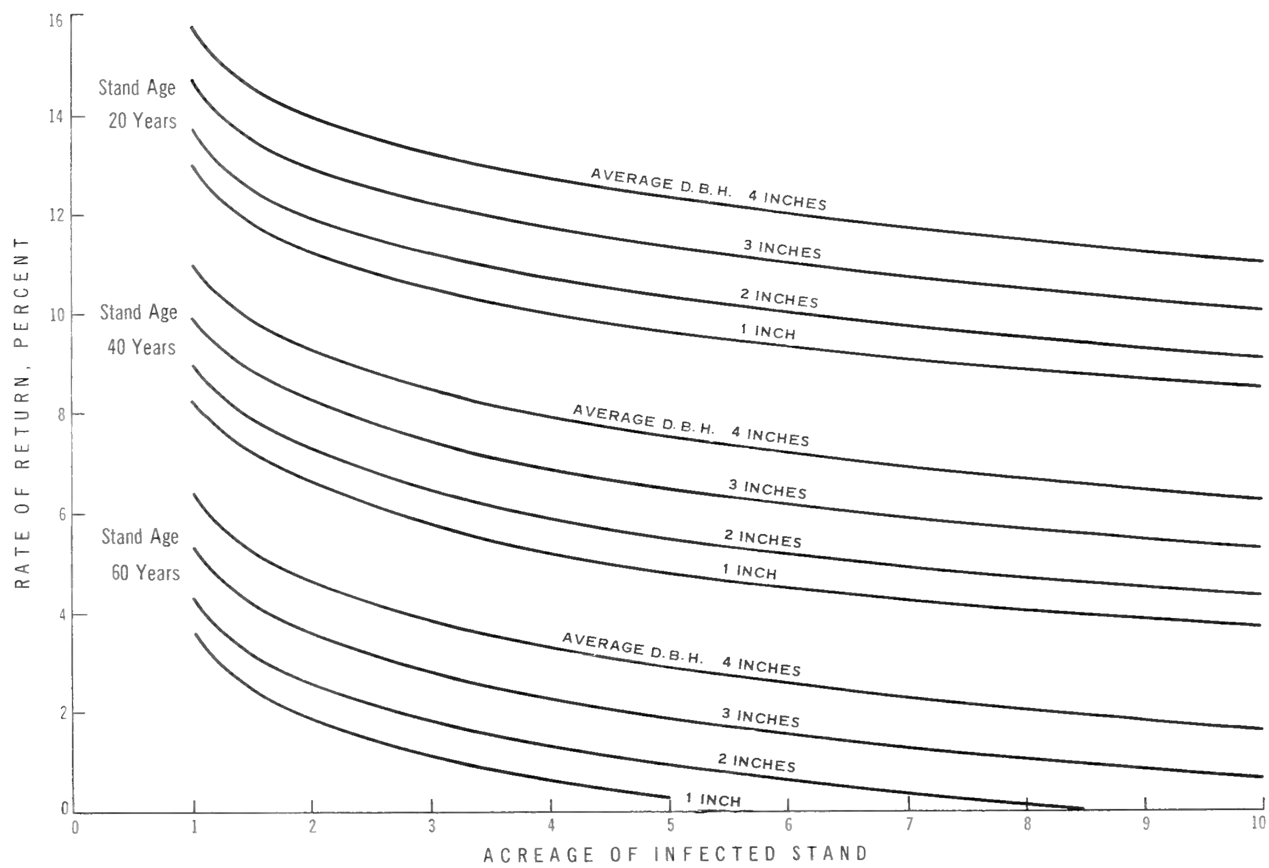

Figure 9.--Rate of return on investment. Dwarfmistletoe control without precommercial thinning. 2,000 stems per acre. Rule: For each increase of stocking by 1,000 stems per acre, subtract 1 percent.

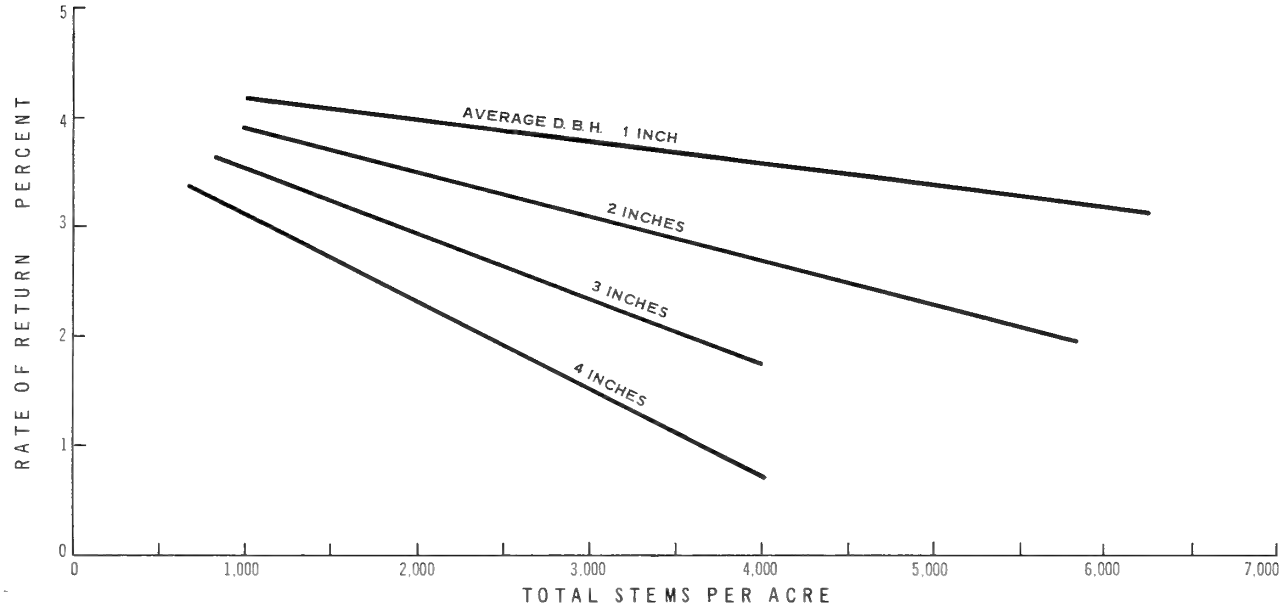

Figure 10.--Rate of return on investment. Dwarfmistletoe control after commitment to precommercial thinning. Site IV; stand age, 20 years. Rule: For each increase of site quality by one class, subtract 3 percent; for each increase of age by 10 years, subtract 1/2 percent.

Figure 10 refers to cases in which policy and budgetary action already call for precommercial thinning of infected stands, so that dwarfmistletoe control involves a separate and subsequent decision. That special consideration is required for such cases is shown by the following example. Suppose that dwarfmistletoe control alone costs $30 per acre and that silvicultural thinning alone costs $30 per acre. However, for the reason of jointness discussed earlier, the two operations together might cost only $50 per acre. If a decision to thin has already been made, and $30 per acre allocated for it, a later decision to add dwarfmistletoe control to the treatment requires adding only $20, not $30, for pest control.

Data

Forest disease researchers at the Pacific Northwest Forest and Range Experiment Station are engaged in dwarfmistletoe investigations from which interim conclusions have been drawn to develop control priorities.

Yield estimates for uninfected, unthinned stands were made from equations developed by Lynch (1958). For thinned, uninfected stands, Forest Service guidelines were employed.[8] Stumpage is valued at $15 per thousand board feet.

INVESTMENT ALTERNATIVES

Three philosophies of treatment are considered. These are:

1. Dwarfmistletoe control concurrent with precommercial thinning.

2. Dwarfmistletoe control in a previously thinned stand, or where a decision to thin has already been made.

3. Dwarfmistletoe control without precommercial thinning.

[8] U.S. Forest Service. National Forest timber stand improvement handbook, Region 6, 1963. Timber management handbook, Region 2, 1956.

COMPUTATIONS

Determination of the rate of return on a stand-treatment investment requires projecting stand growth through a rotation, with and without treatment. Next, economic value must be assigned to the yield differential. For a public agency, the economic impact of stand treatment is its effect on the allowable cut. Dwarfmistletoe control is generally followed by marked increase in growth on the treated area. Because anticipated growth enters the allowable cut calculation, an expected growth increase on part of a working circle must affect the overall allowable cut to some degree. Even if treatment of a juvenile stand produces no immediate change in merchantable yield from the stand treated, the resulting change in calculated allowable cut leads to an immediate increase in merchantable timber cut from other stands.[9]

Calculations made for this publication incorporated the foregoing allowable cut consideration. Rates of return presented here would be inapplicable to forest managers whose cutting plans are not affected by growth estimates.

The cost, growth response, economic impact, and rate of return on investment were calculated for over 4,000 young stands for each of the three control philosophies. Stands differed according to site class, age, average d.b.h., degree of infection, stocking level, size of infected area, and distance from town. The last factor affects both travel cost for crews doing stand treatment and hauling cost of logs sold.

[9] No real increase in cut would be created in a working circle lacking a backlog of merchantable timber, but this circumstance is rare in the West.

Results of the stand projections and rate-of-return calculations were used to develop rate-of-return charts, figures 8 through 10. It was found that some factors--for example, degree of infection--are not significantly helpful in predicting the rate of return on treatment investment. Hence, such factors are not employed in the charts.

USING THE CHARTS

Assignment of treatment priorities to individual stands requires a type map or a list of stands identified as to location. In either case, information about each stand must be obtained from field examination, previous experience in the area, or in some instances from aerial photographs. The kinds of information needed can be determined by examining the charts. For example, to use figure 8, one must know site quality, average d.b.h., stocking in stems per acre, and the acreage involved.

Arabic numerals along the vertical axes in figures 8 to 10 indicate rate of return in percent on treatment investment. Stands with high numbers should receive high priority for treatment.

Obviously, rigid use of the charts is possible only where (1) stands are accessible, (2) cutting plans permit overstory removal before treatment of juvenile stands below, (3) commercial timber production is the principal objective of stand management, and (4) assumptions made in this report are valid.

SUMMARY-- STEPS TO FOLLOW IN USING THE GUIDES

ESTIMATING THE COST OF DWARFMISTLETOE CONTROL

1. From column 1, below, select the kind of stand treatment to be used.

2. Collect the types of information about each infected stand indicated in column 2.

3. With the data for each stand, use the chart(s) listed in column 3 to estimate that stand's treatment cost per acre.

4. Multiply treatment cost per acre by the acreage of the infected stand to obtain total cost of treating the stand.

5. Multiply treatment cost by an adjustment factor from table 1.

6. Add about $5 per acre for each recleaning anticipated.

COLUMN 1-- kind of treatment	COLUMN 2-- stand data to collect	COLUMN 3-- use figure(s)
Pruning-felling with precommercial thinning	Average d.b.h.; total stems per acre; infected stems per acre	4, 5
Pruning-felling without precommercial thinning	Average d.b.h.; total stems per acre; infected stems per acre	5, 6
Felling-only with precommercial thinning	Average d.b.h.; total stems per acre	7

ESTIMATING RATES OF RETURN ON INVESTMENT IN DWARFMISTLETOE CONTROL

1. From column 1, below, select the kind of investment to be made.

2. Collect the types of information about each infected stand indicated in column 2.

3. With the data for each stand, use the chart(s) listed in column 3 to estimate the rate of return on investment involved in that stand.

4. List the stands by their location and estimated rate of return, starting with the highest return stand and working down.

5. Schedule for earliest treatment those stands appearing first in the list.

6. In general, treat only stands that are within one-fourth mile of a suitable access road. Treatment cost increases disproportionately as walk-in distance increases, reducing return on investment to unattractive levels.

COLUMN 1-- kind of investment	COLUMN 2-- stand data to collect	COLUMN 3-- use figure
Control with precommercial thinning	Average d.b.h.; total stems per acre; site class; acreage of infected stand	8
Control without precommercial thinning	Average d.b.h.; total stems per acre; site class; acreage of infected stand; stand age	9
Control after a commitment has been made to thin precommercially	Average d.b.h.; total stems per acre; site class; stand age	10

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The FOREST SERVICE of the U. S. DEPARTMENT OF AGRICULTURE is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.